

Landsat 5 reflectance and NDVI 27-year time series inconsistencies due to satellite orbit change

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Landsat 5

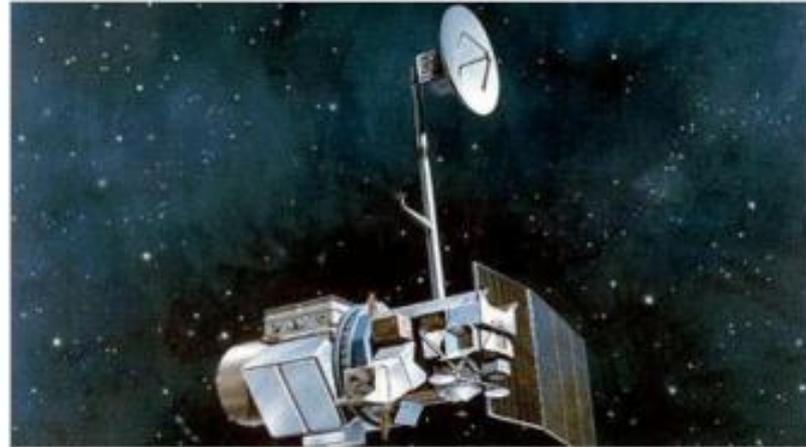
Landsat 5 was only designed to operate for three years, but has lasted 29.

By SPACE.com

Thu, Feb 21 2013 at 11:15 AM



Related Topics: [NASA](#), [Space](#)



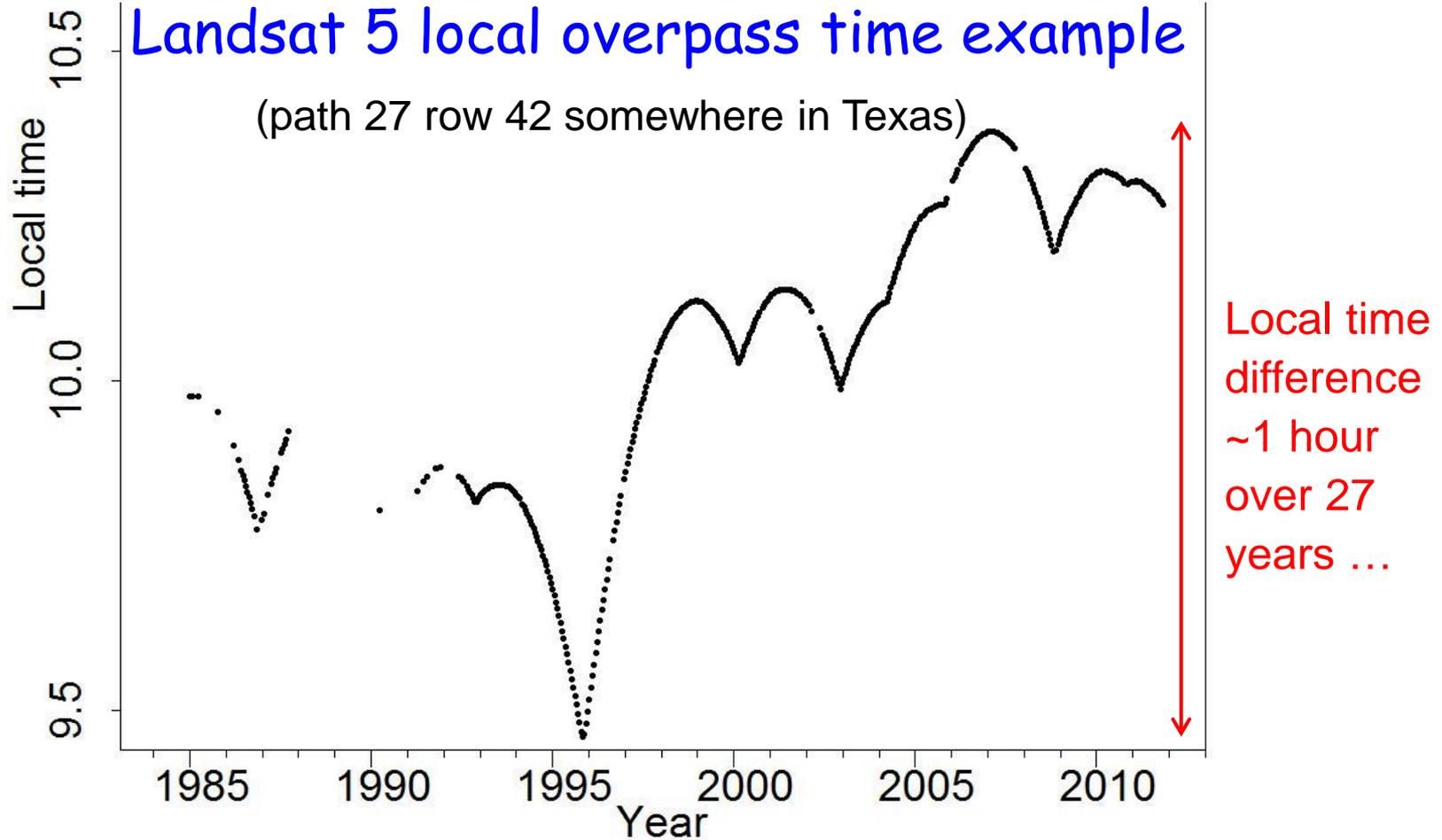
NASA's Landsat 5 satellite floating far above the Earth (Photo: USGS)

Landsat 5 has secured a new world record title for being the longest-operating Earth observation satellite after almost three decades in orbit.

Guinness World Records sent an email confirmation to [NASA's Goddard Space Flight Center](#) in Greenbelt, Md., informing space agency officials of the honor, NASA officials said in a [statement](#)

- 9:45 a.m Mean Local Time of Descending Node (MLTDN)
 - *initially* orbit maintained by periodic station keeping maneuvers to maintain ground track and orbit phase with Landsat 4
 - *initially* MLTDN required to not vary by more than ± 15 minutes of 9:45 a.m

Landsat 5 local overpass time example



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 - *initially* MLTDN required to not vary by more than ± 15 minutes of 9:45 a.m

Nadir view Reflectance varies with solar zenith

SZ=65°, more shadow, lower ρ_{red}

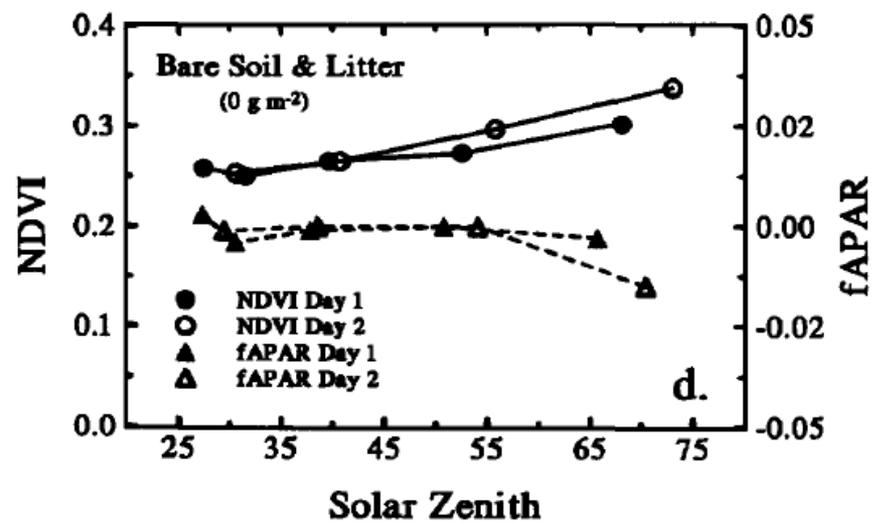
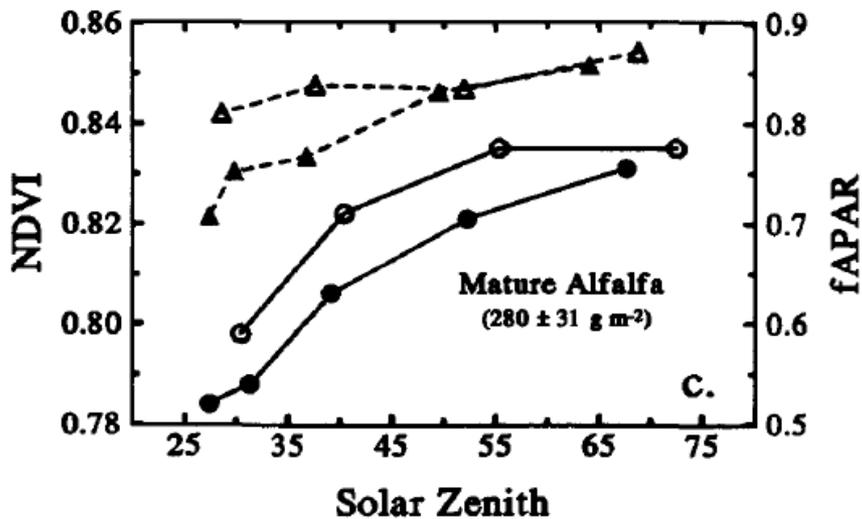
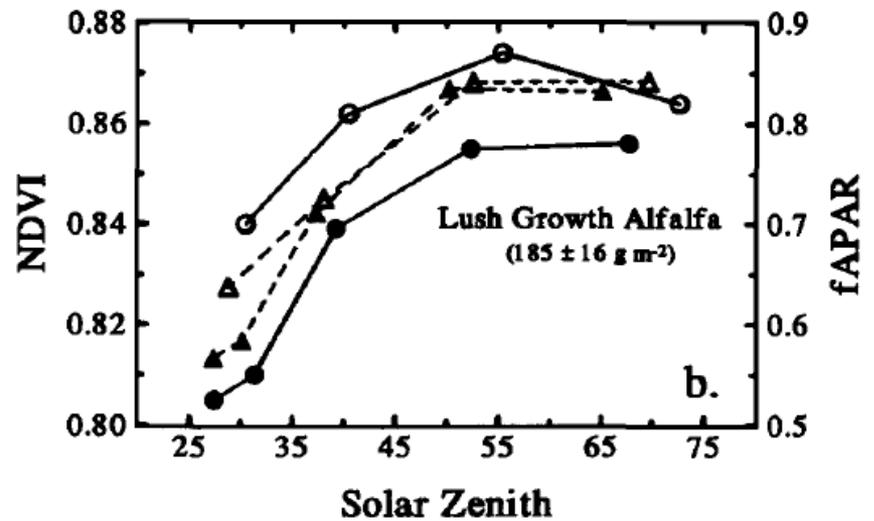
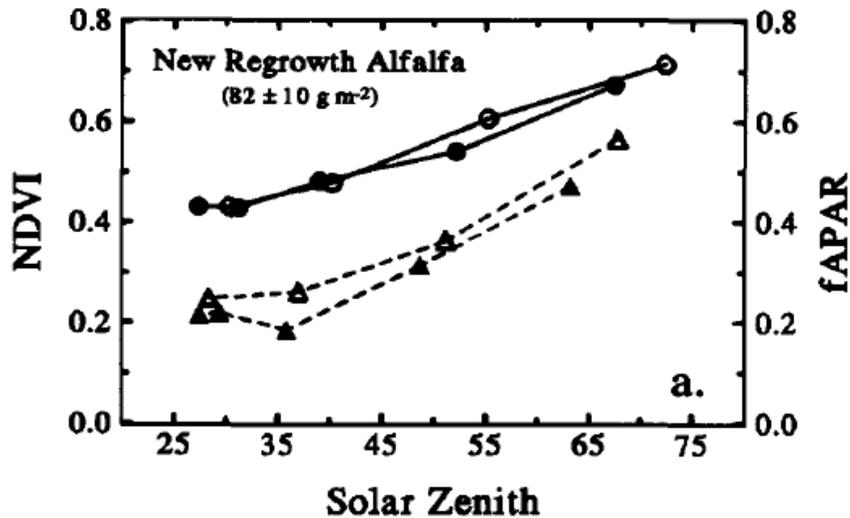


SZ=40°, less shadow, higher ρ_{red}

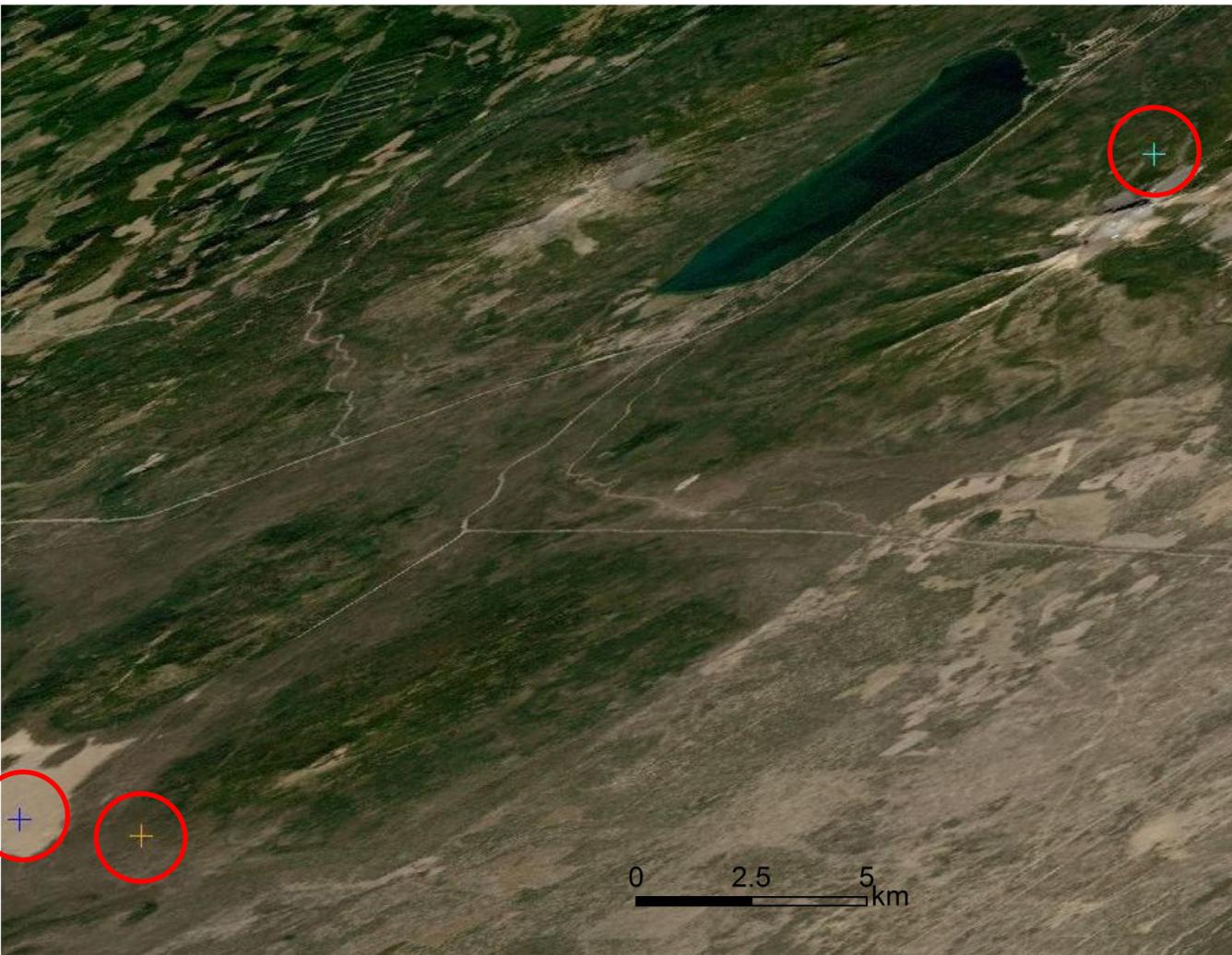


Deering, D. W., Eck, T. F., & Banerjee, B. (1999). Characterization of the reflectance anisotropy of three boreal forest canopies in spring – summer. *Remote Sensing of Environment*, 67, 205 – 229.

NDVI vs Solar Zenith (Pinter 1993, RSE)



Can we see Landsat 5 orbit drift effects in TM images?



Considers

- 3 sites (Vogelmann et al. 2016 *RSE*), Crater Lake National Park, Oregon

At each site:

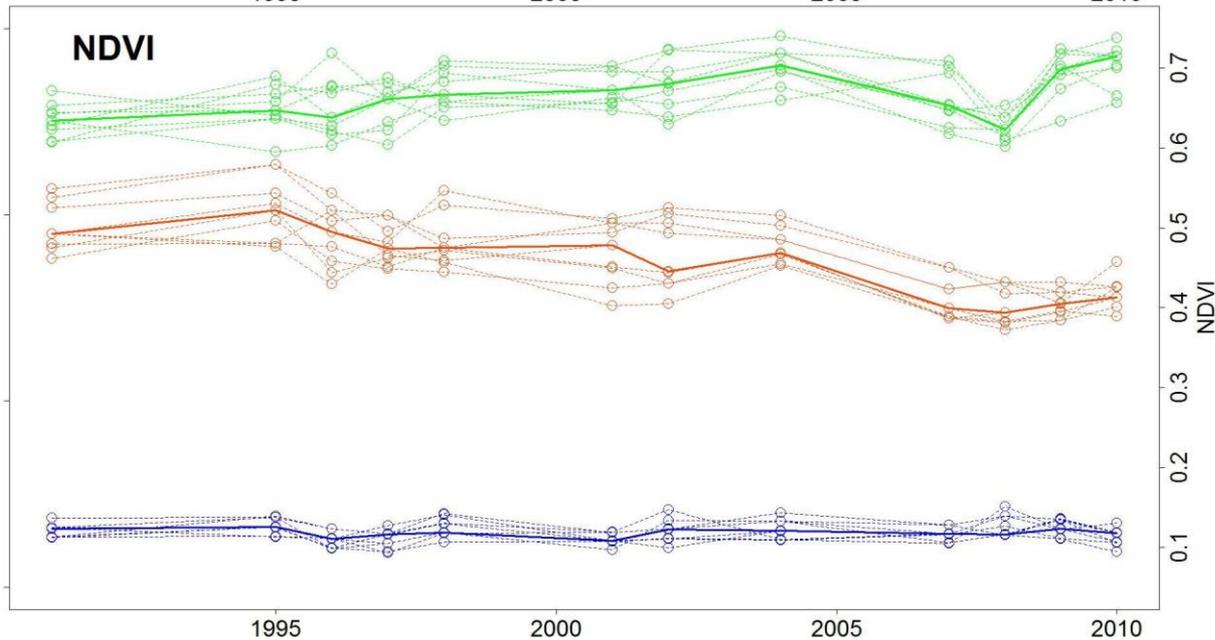
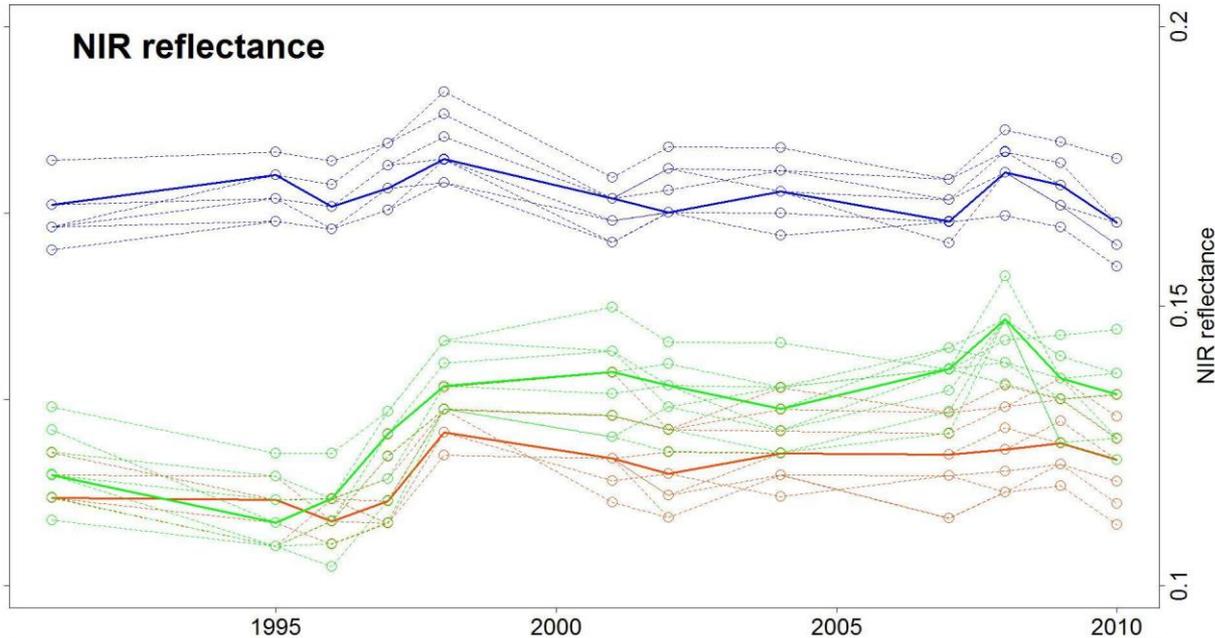
- 9 adjacent 30m pixels
- 12 L1T Landsat 5 cloud-free images spanning 1991-2010
- Atmospherically corrected
- summer anniversary date images (no more than ± 5 days of Sep. 1)

3 SITE TIME SERIES

Blue: sparsely vegetated pumice desert

Green: coniferous forest with gradual NDVI increase

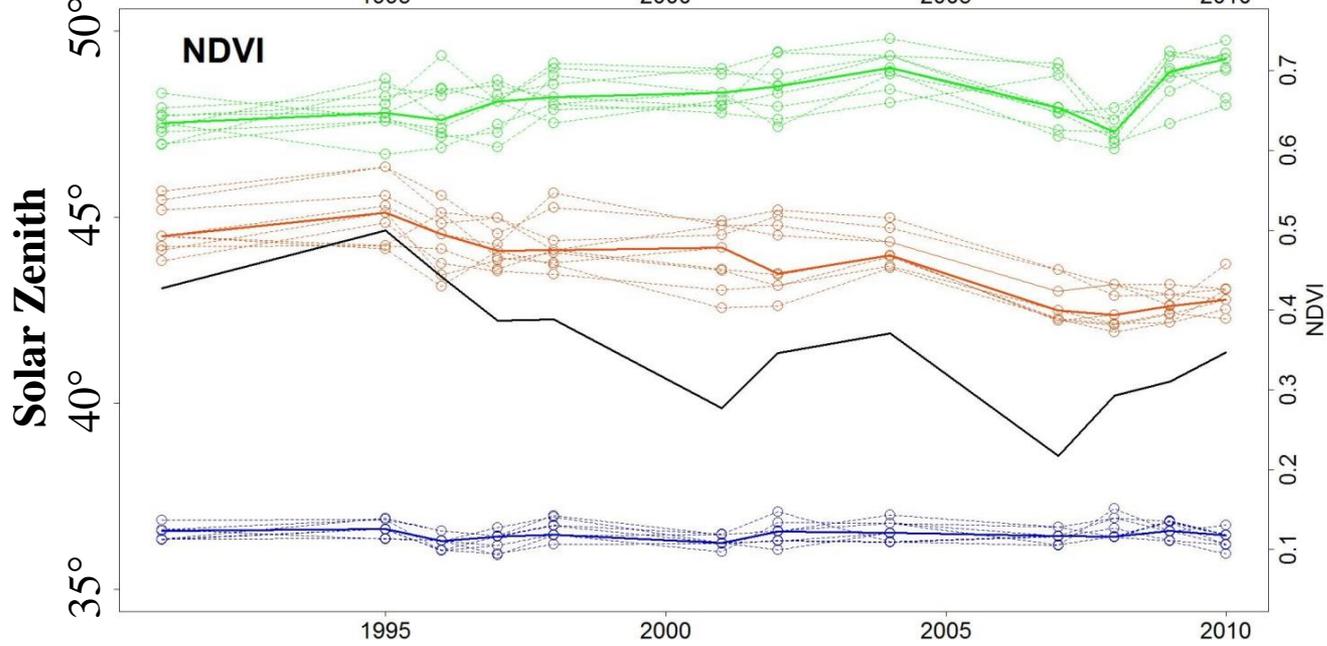
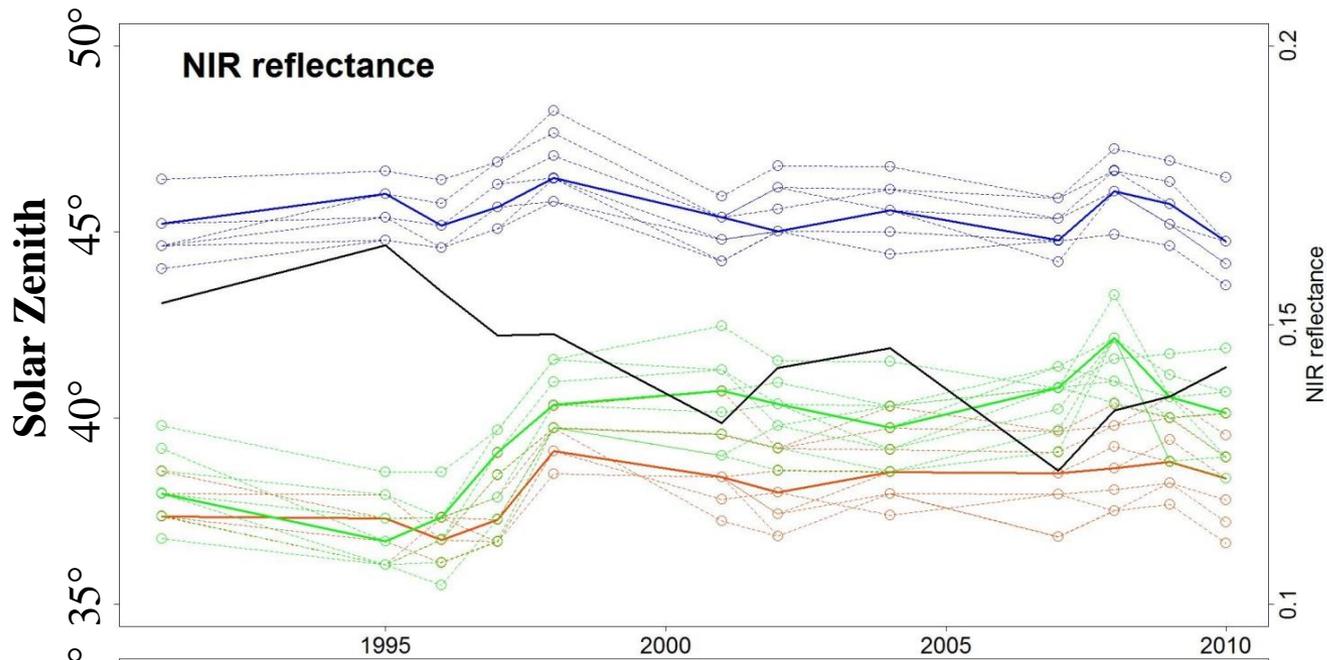
Orange: coniferous forest with gradual NDVI decrease



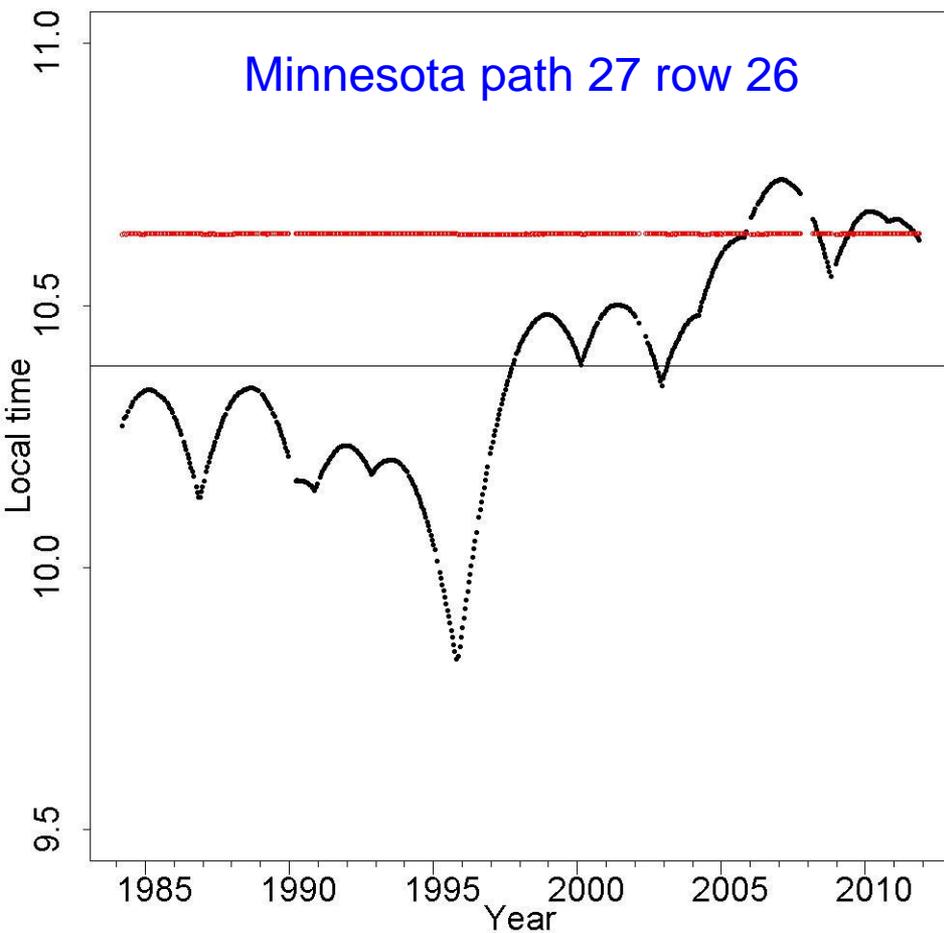
Open circles
- 9 individual pixel values

Solid colored lines
- median of 9 pixel values

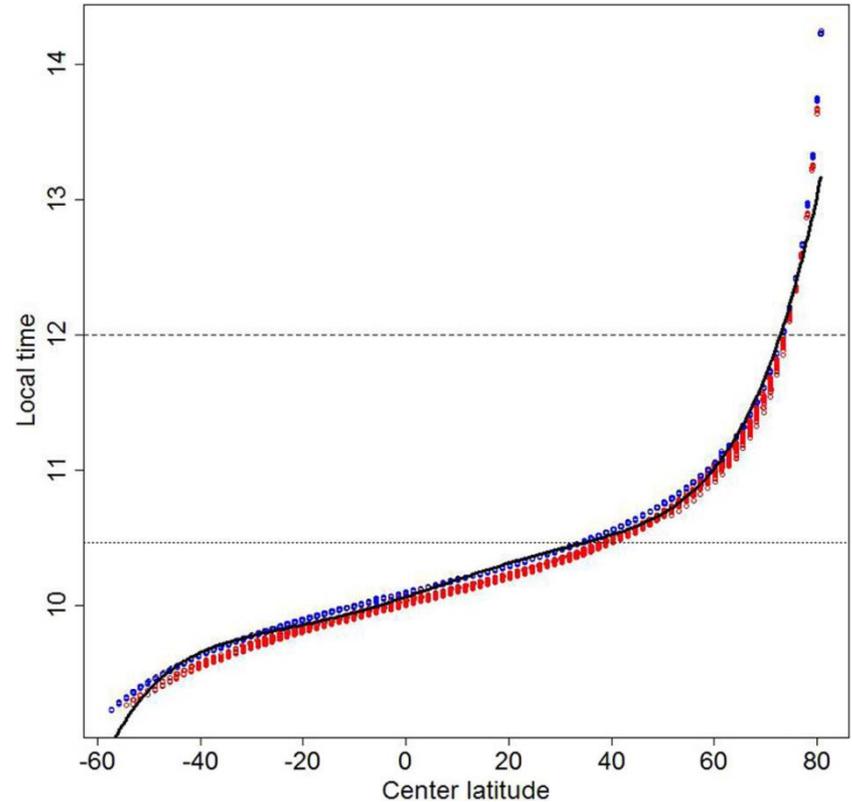
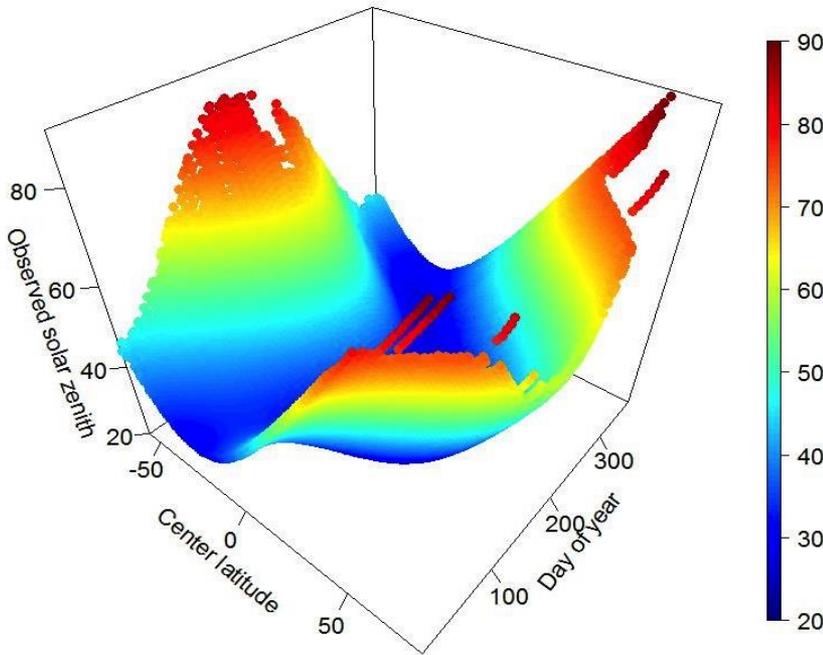
3 SITE TIME SERIES



Landsat 5 TM local overpass times
for 2 sites same path but different rows
2011 reference overpass time (red dots)



2011 reference overpass time and solar zenith based on 12 months of non-Antarctic Landsat metadata values

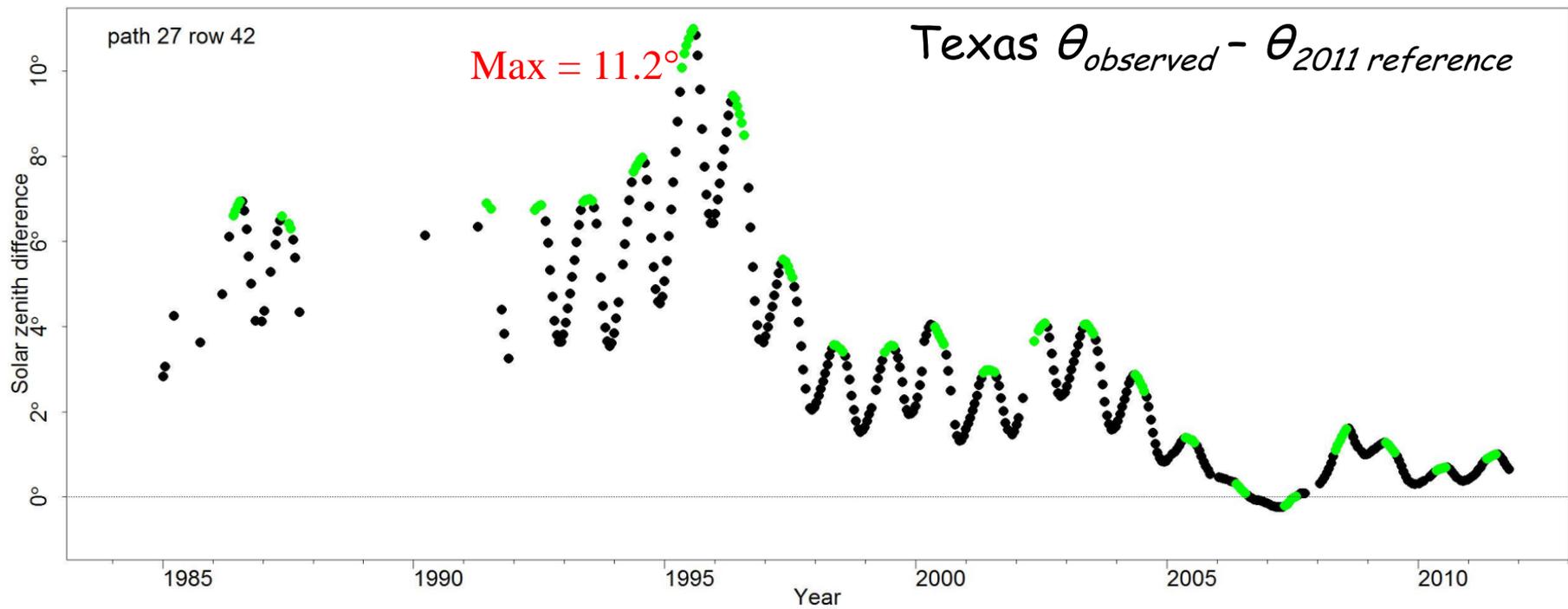
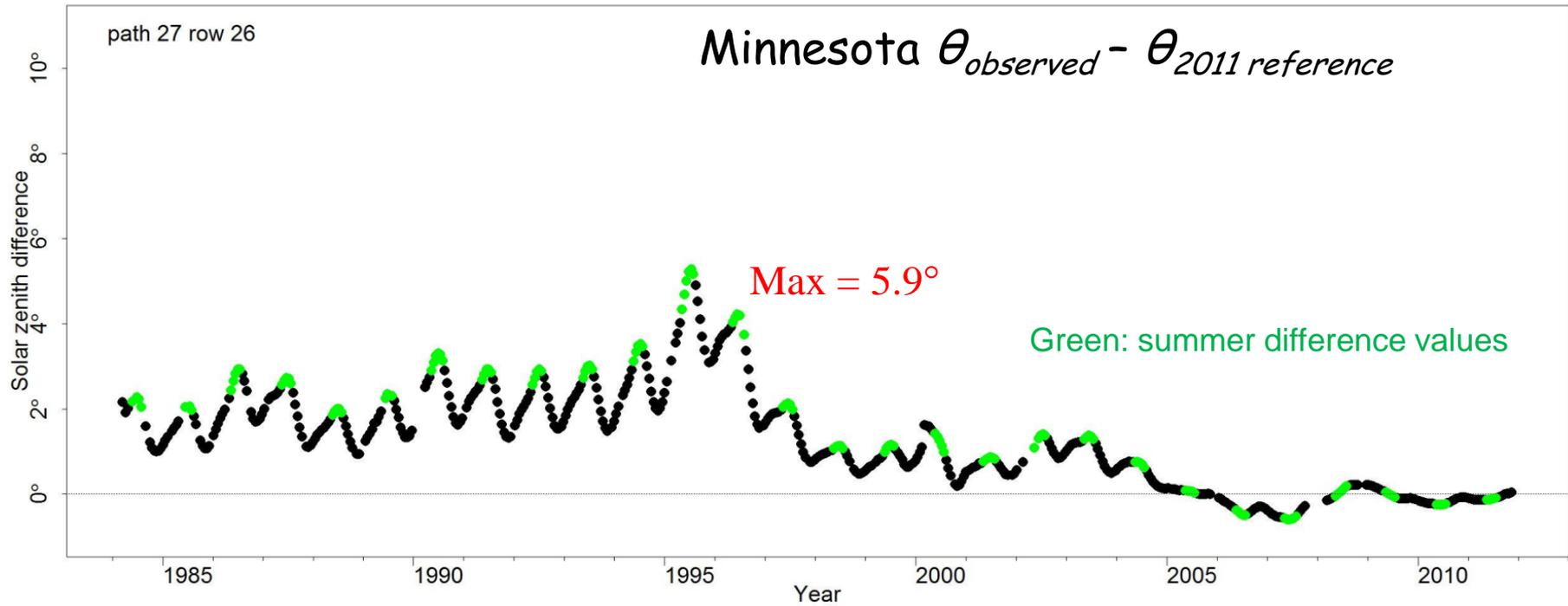


$$22.14^\circ \leq \theta_s \leq 89.71^\circ \quad \theta_s \text{ mean} = 43.23^\circ$$

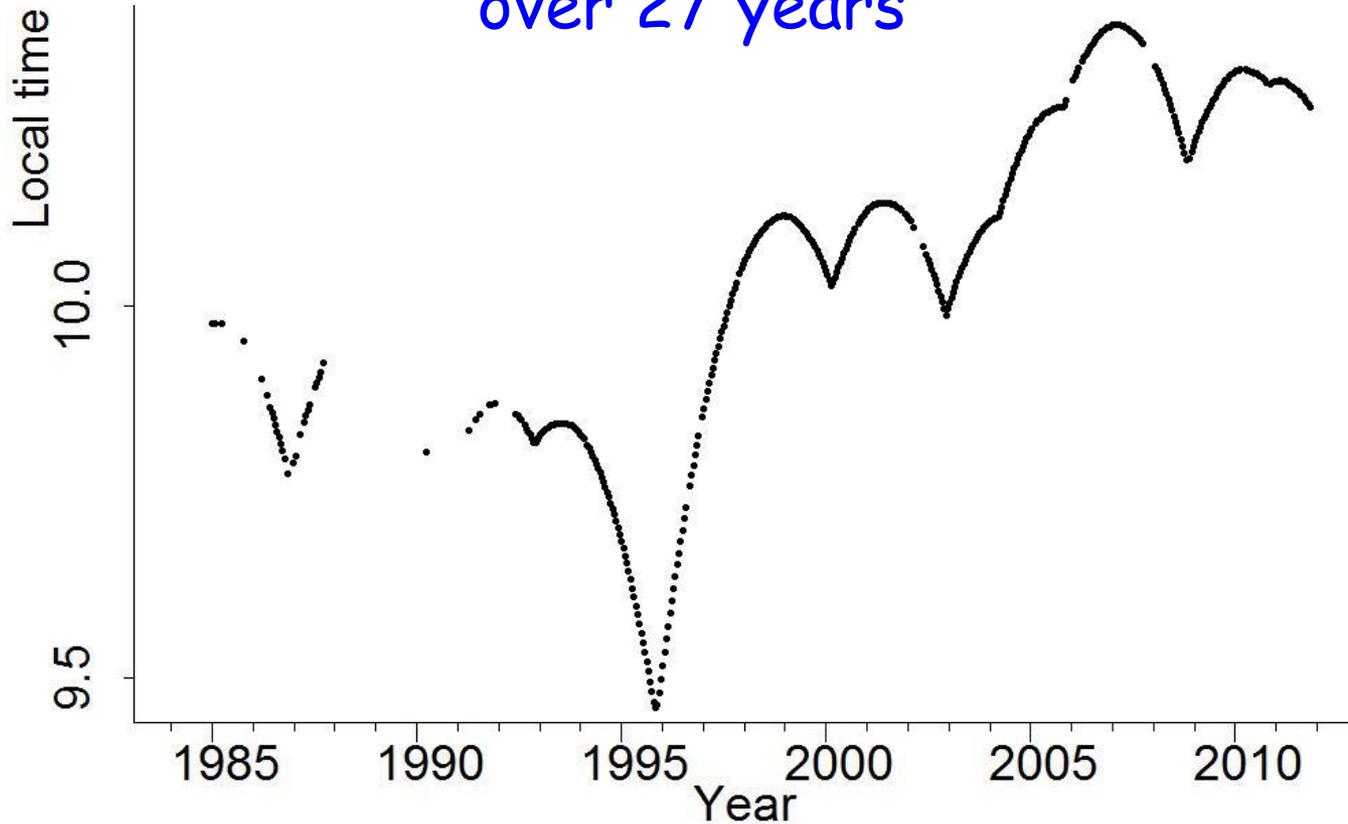
$$\hat{t}_{local} = 1.36292 \times 10^{-9} \alpha^5 - 3.15403 \times 10^{-8} \alpha^4 - 3.15819614 \times 10^{-6} \alpha^3 + 0.0000652685643 \alpha^2 + 0.0120604786763 \alpha + 10.06$$

where α is latitude

$$Q_{2011 \text{ reference}} = f(t_{local}, \text{date}, \text{latitude})$$



Modeling the reflectance impacts of overpass time and so solar zenith change over 27 years

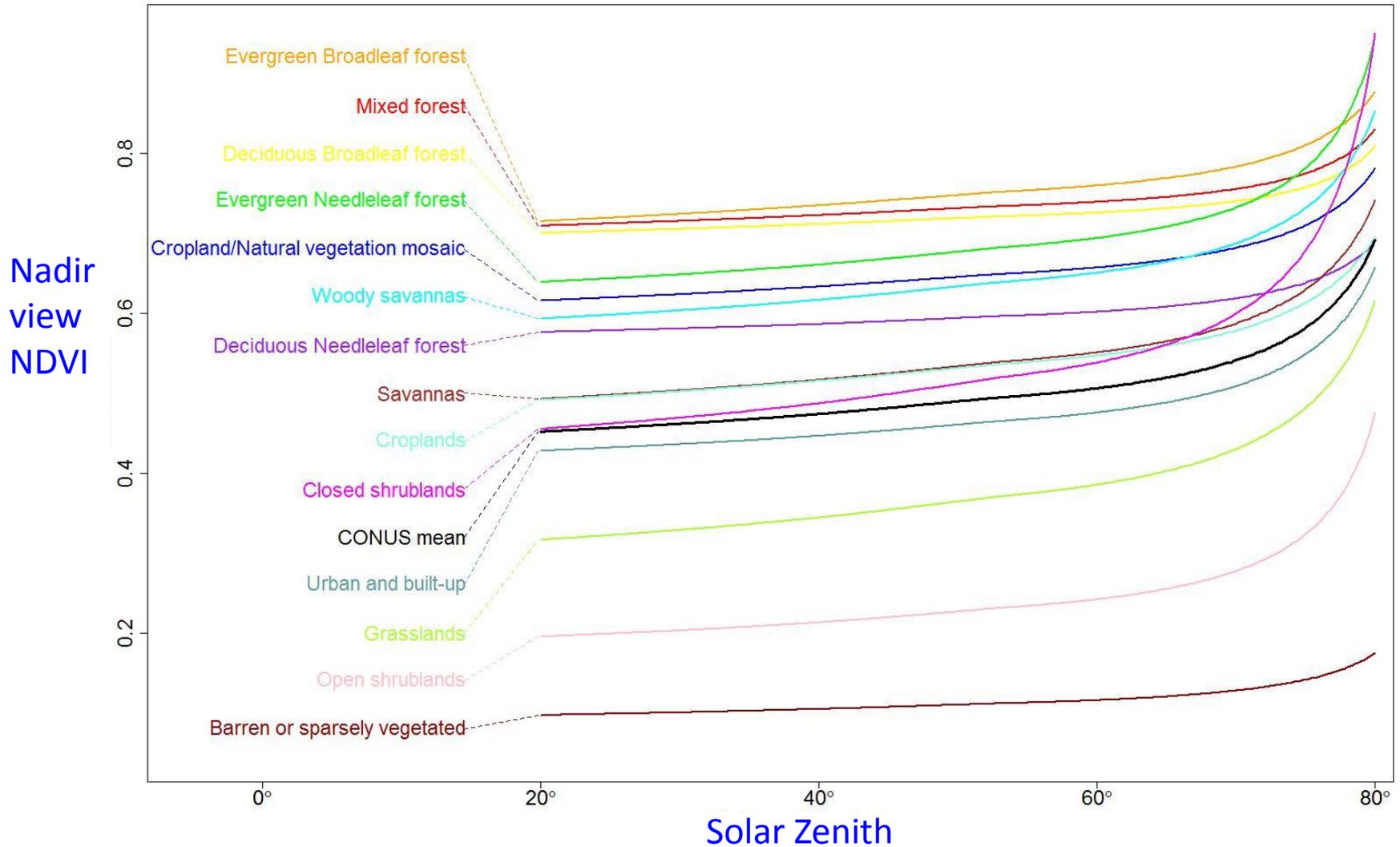


$$NBAR_{obs,\lambda} = f(\theta_{s=obs}, \theta_{v=0}, \text{MODIS BRDF parameters for } \lambda)$$

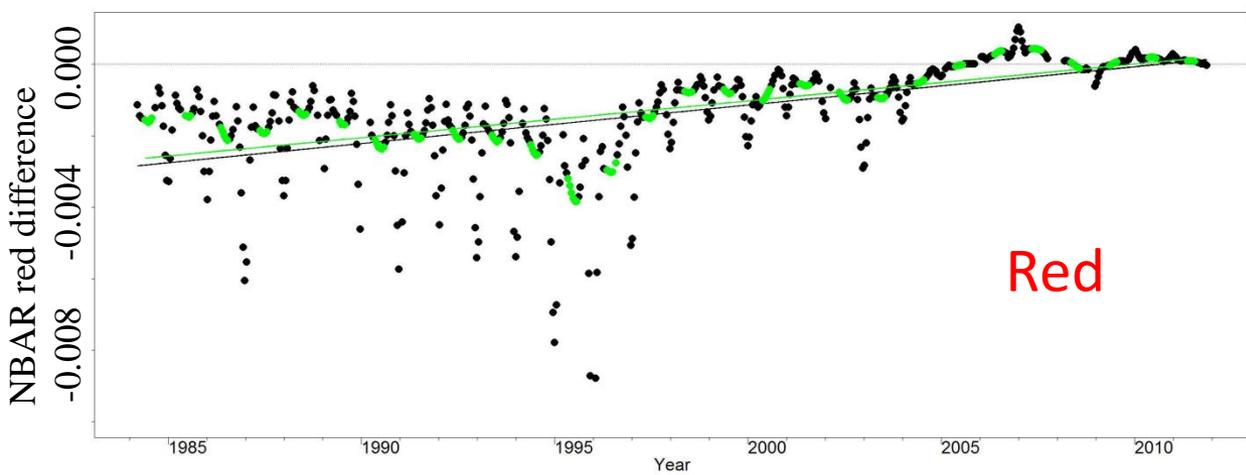
$$NBAR_{reference,\lambda} = f(\theta_{s=2011reference}, \theta_{v=0}, \text{MODIS BRDF parameters for } \lambda)$$

consider

different mean CONUS land cover MODIS BRDF parameters



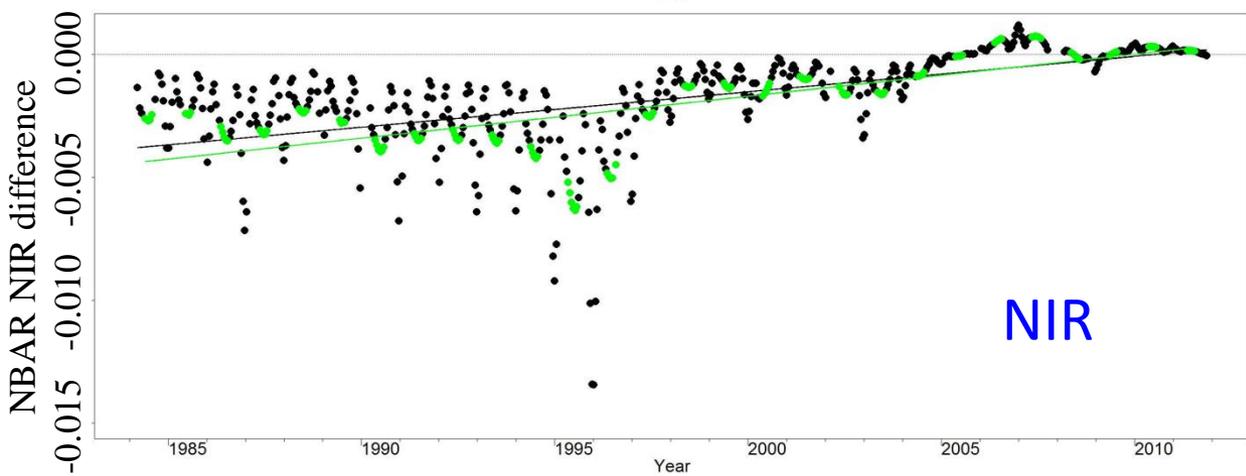
Roy, D.P., Zhang, H. K., Ju, J., Gomez-Dans, J. L., Lewis, P.E., Schaaf C.B., Sun, Q., Li, J., Huang, H., & Kovalskyy, V., 2016b, A general method to normalize Landsat reflectance data to nadir BRDF adjusted reflectance, *Remote Sensing of Environment*. 176, 255-271.



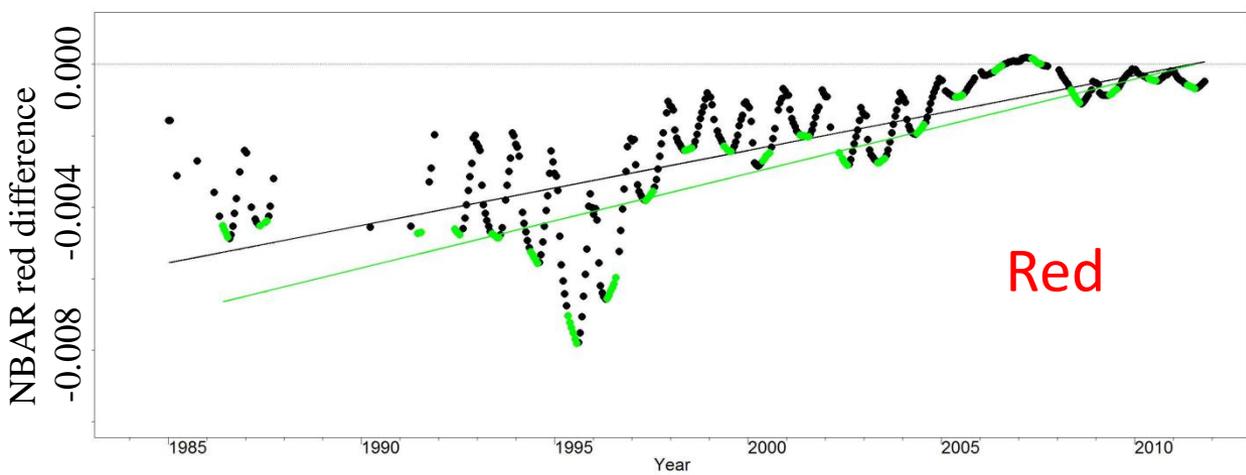
Minnesota path/row

modeled NBAR
difference

$$NBAR_{obs, /} - NBAR_{2011\ reference, /}$$



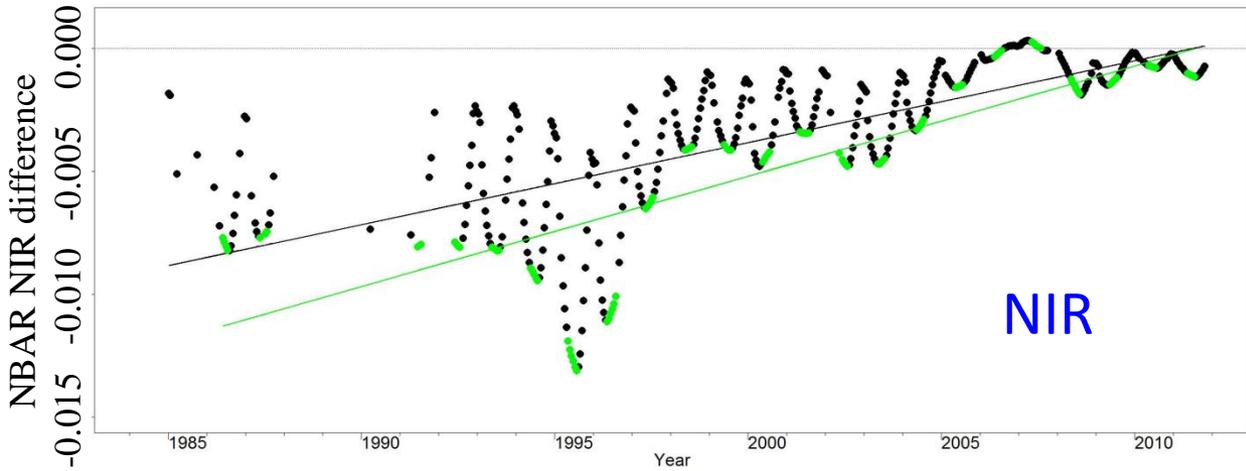
closed
shrubland class



Texas path/row

modeled NBAR
difference

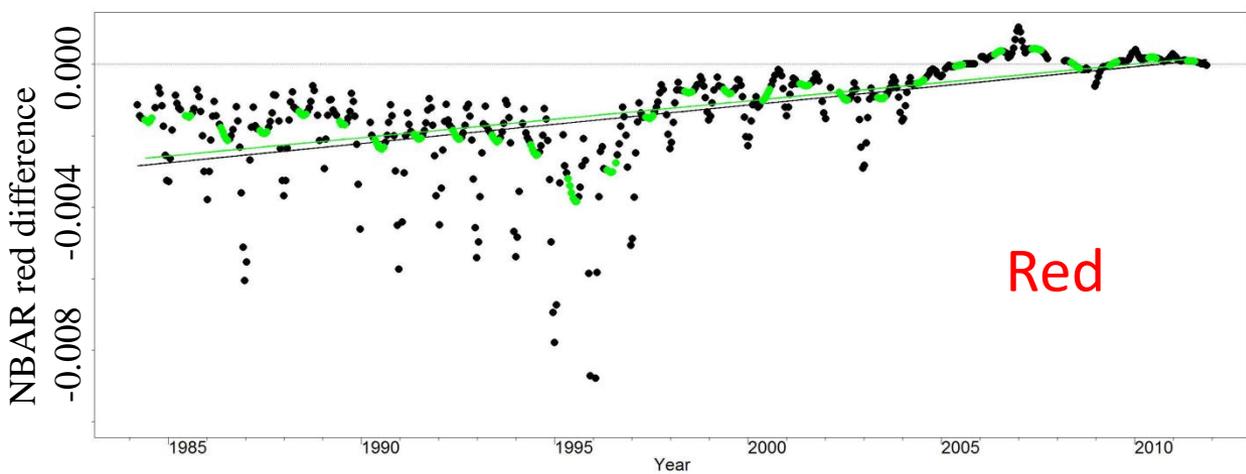
$$NBAR_{obs, /} - NBAR_{2011\ reference, /}$$



closed
shrubland class

NIR

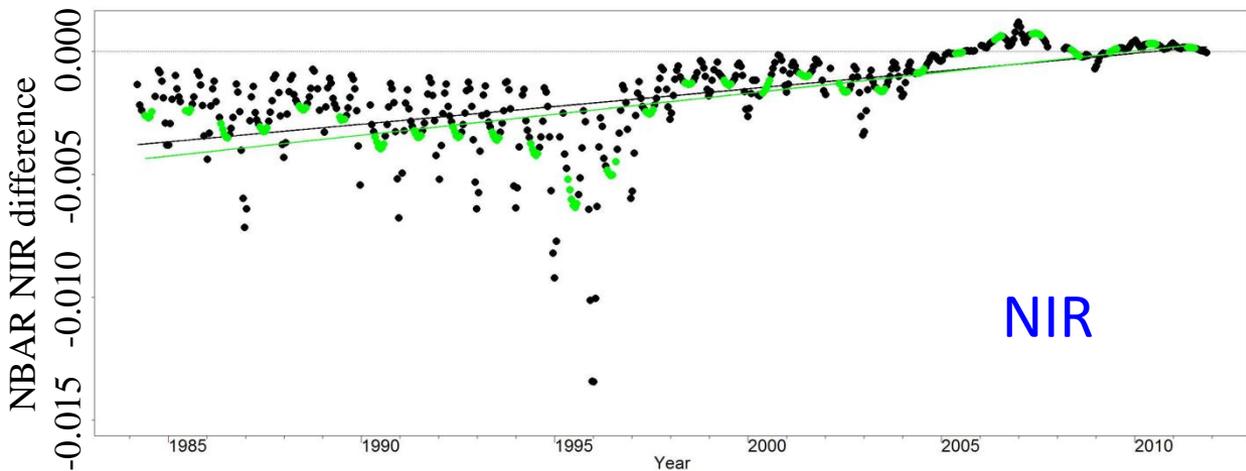
Green:
modeled NBAR difference
summer images only



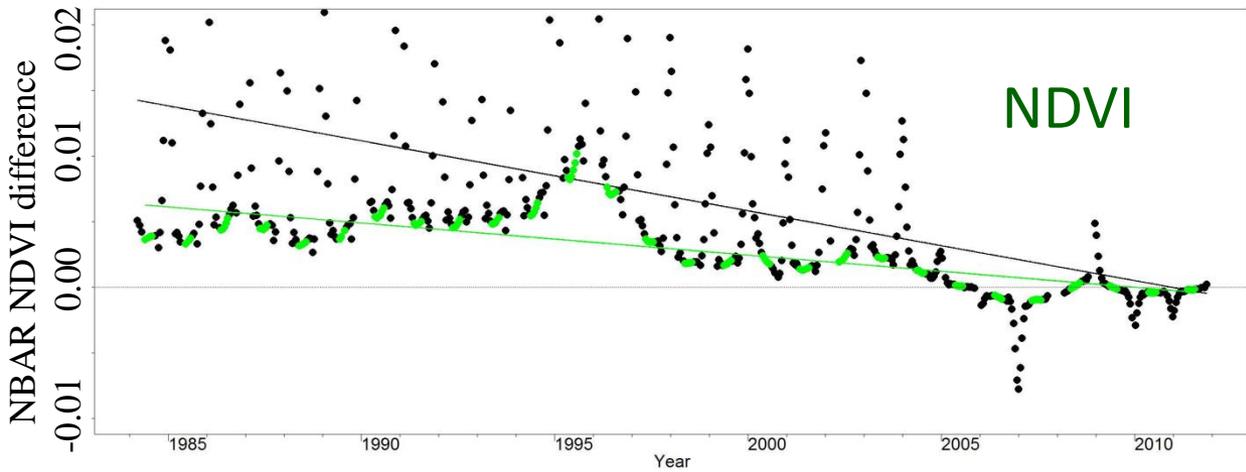
Minnesota path/row

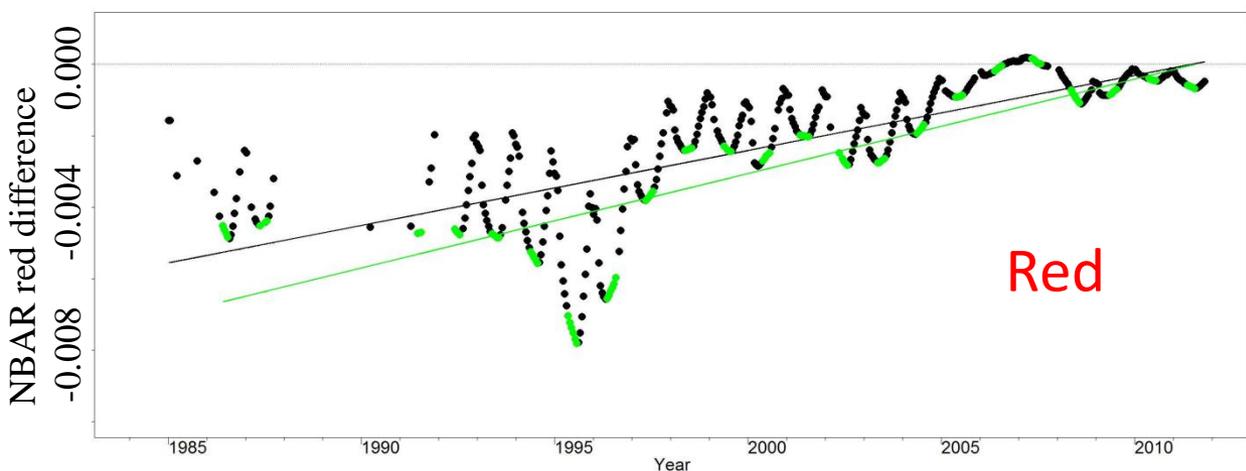
modeled NBAR
difference

$$NBAR_{obs, /} - NBAR_{2011\ reference, /}$$



closed
shrubland class

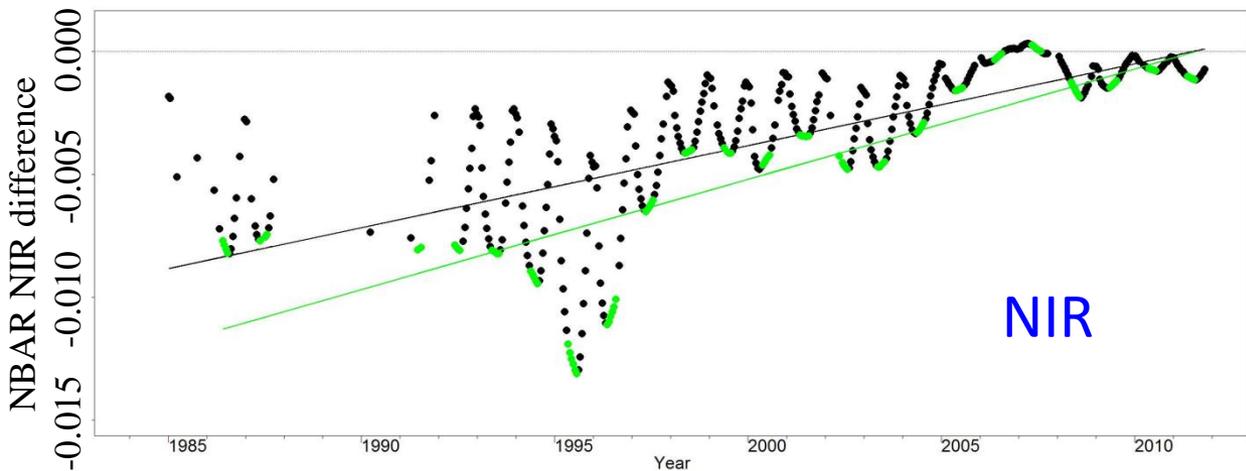




Texas path/row

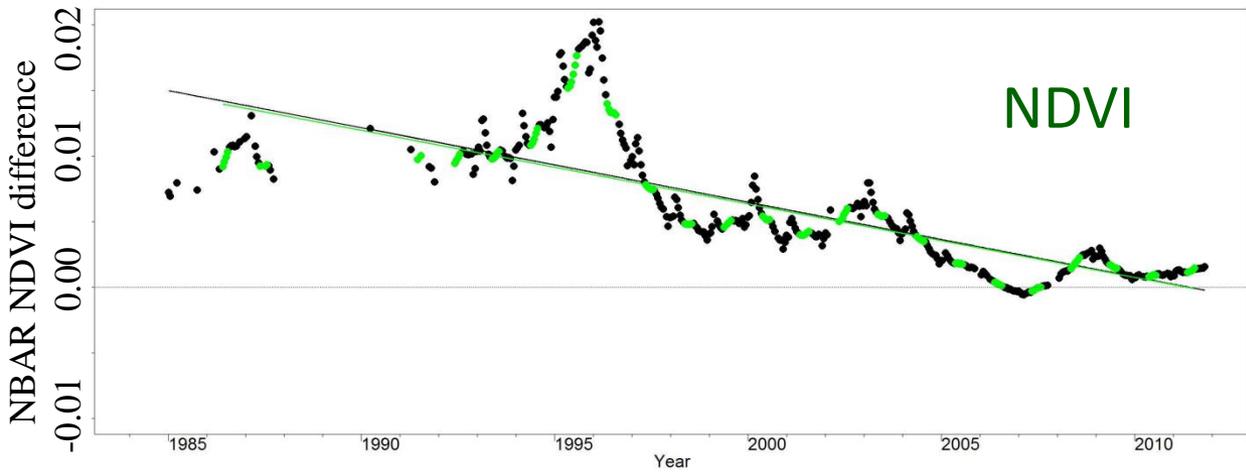
modeled NBAR
difference

$$NBAR_{obs, /} - NBAR_{2011\ reference, /}$$



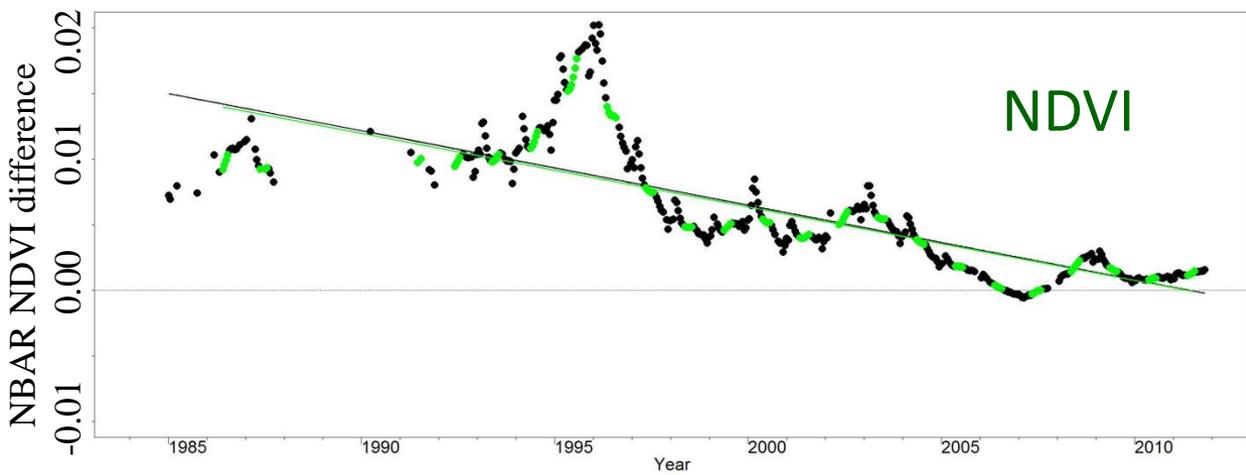
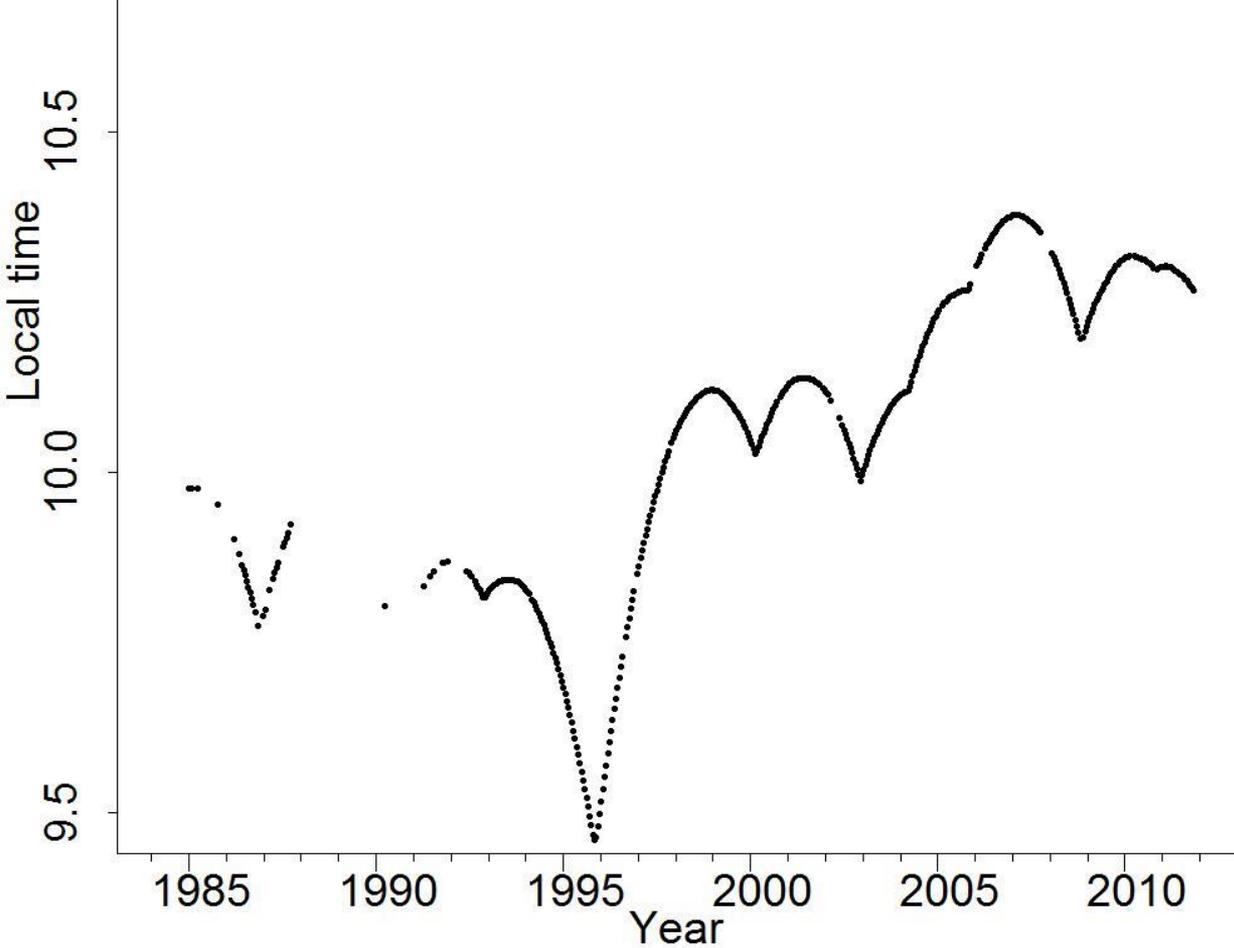
closed
shrubland class

NIR



Green:
modeled NBAR difference
summer images only

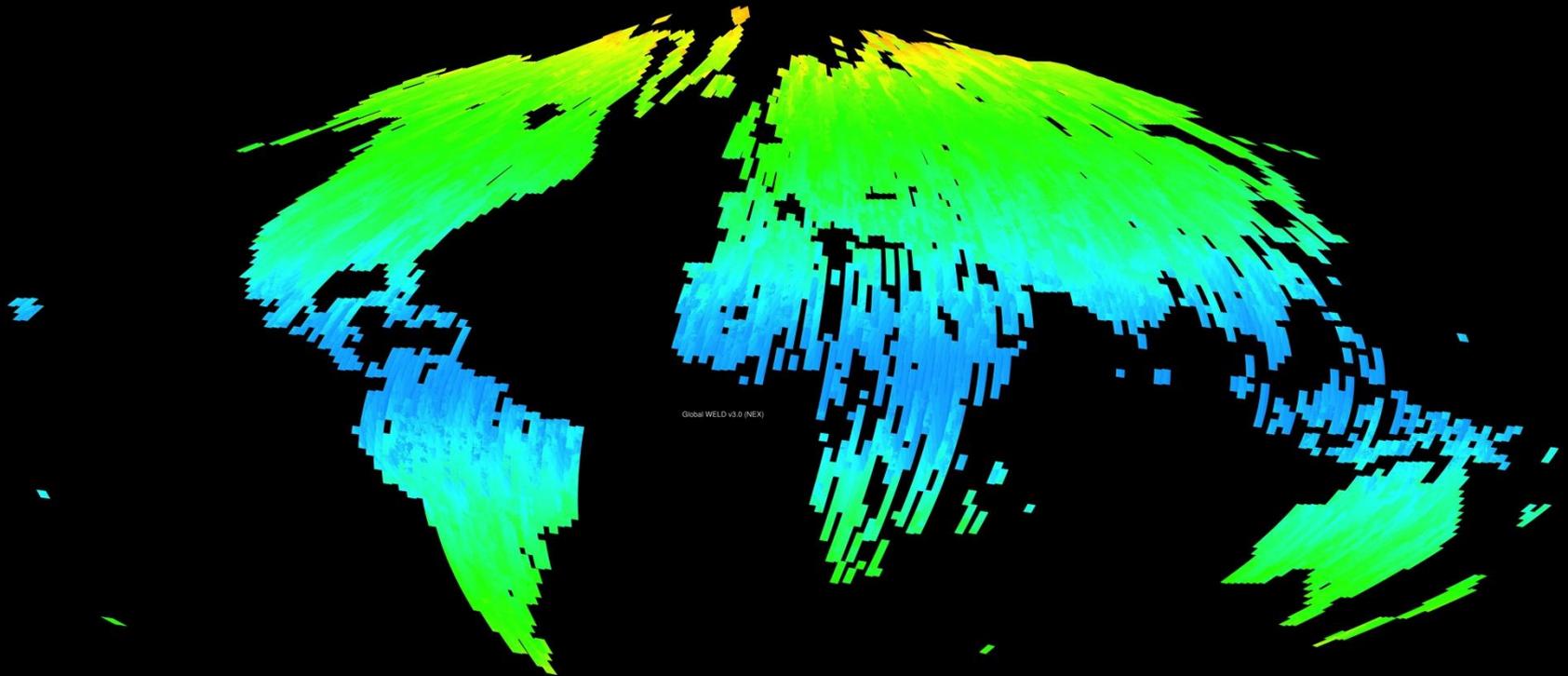
NDVI



Conclusions

- Landsat 5 orbit changed considerably over 27 year life
 - Overpass time changed by up to ~1 hour ($\gg \pm 15$ mins of 09:45 AM MLTDN)
 - Solar zenith changed by $>10^\circ$
- Can see orbit shift in actual Landsat 5 time series
- BRDF modeling findings
 - 27-year NDVI change trend 0.0006 NDVI/year, small but not insignificant
 - Comparing certain years, i.e., 1995 and 2007 may not be a good idea
 - $\text{NDVI}_{1995} 0.11 > \text{NDVI}_{2007}$ for anisotropic land cover types
 - $\text{NDVI}_{1995} 0.05 > \text{NDVI}_{2007}$ for average CONUS land cover types
- Further research to develop a Landsat BRDF normalization approach for Landsat 5 orbit drift changes is recommended
- Zhang, H.K and Roy, D.P., Landsat 5 Thematic Mapper reflectance and NDVI 27-year time series inconsistencies due to satellite orbit change, *RSE*, In review

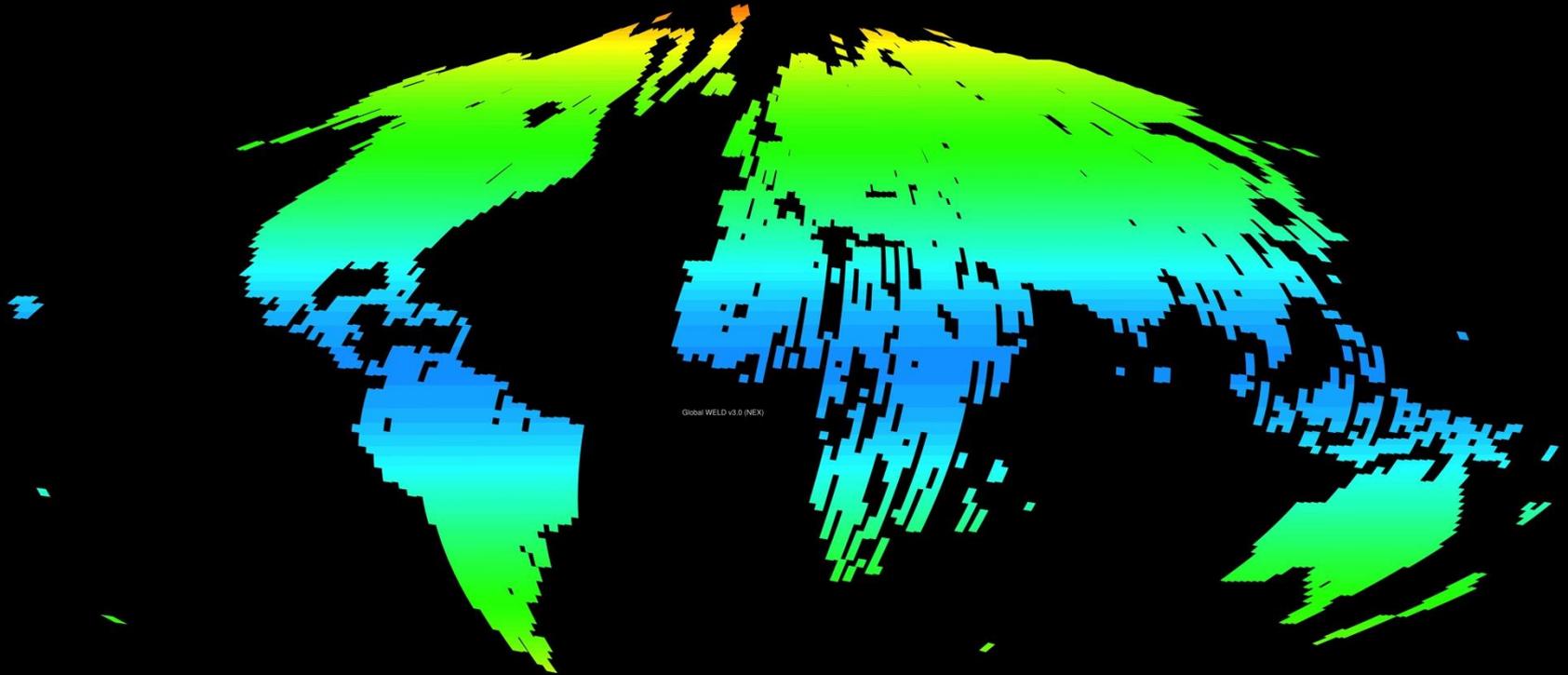
WELD Landsat 5 & 7 observed Solar Zenith



Global WELD NEX Version 3.0 September 2009 30m product
from 15,058 L1T scenes (7,328 Landsat 5 & 7,730 Landsat 7)

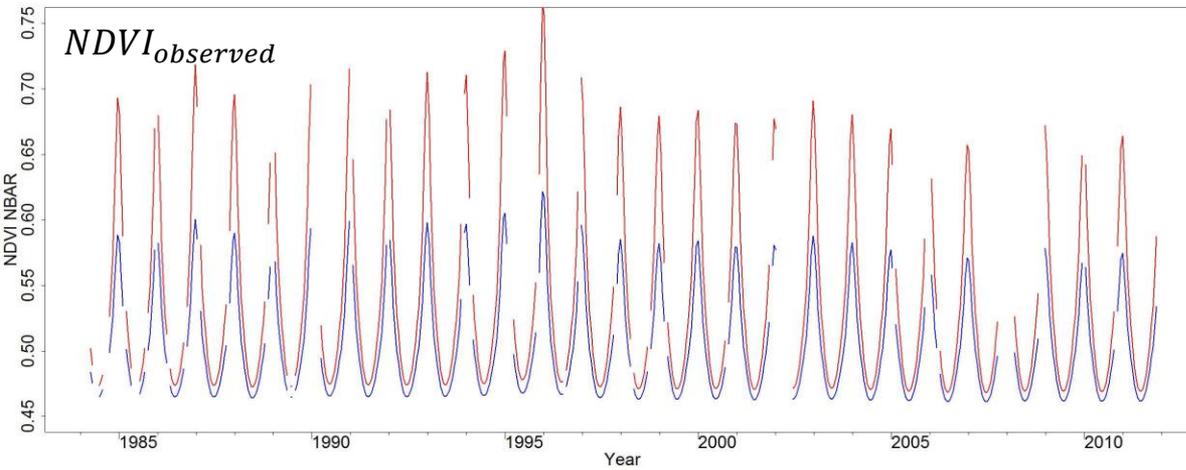
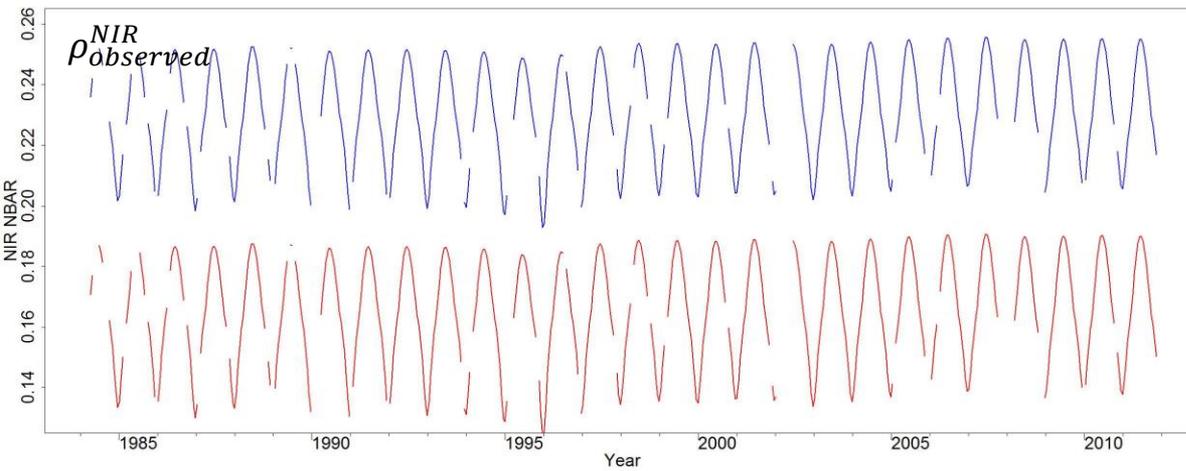
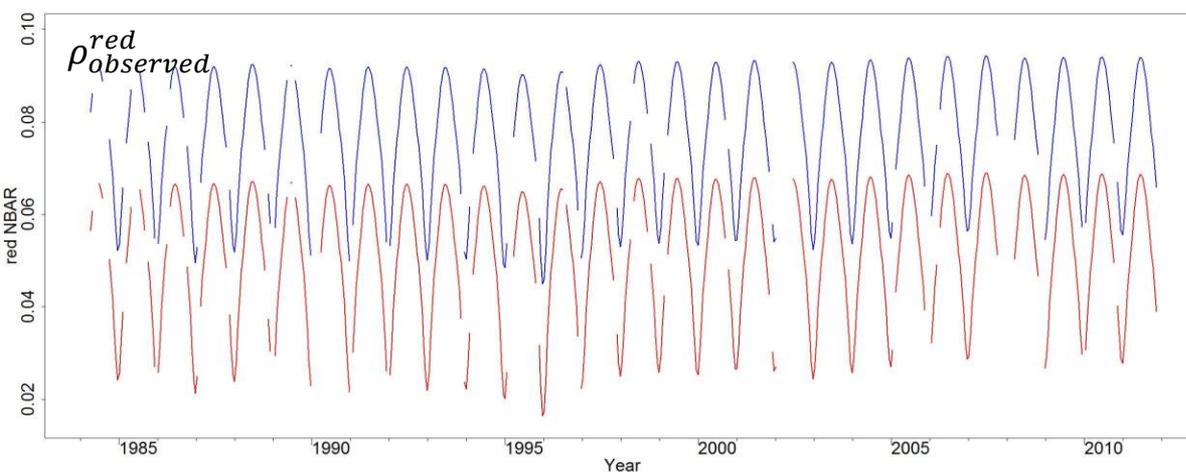
Sinusoidal Equal Area Projection

WELD Landsat 5 & 7 modeled Solar Zenith used to derive WELD NBAR

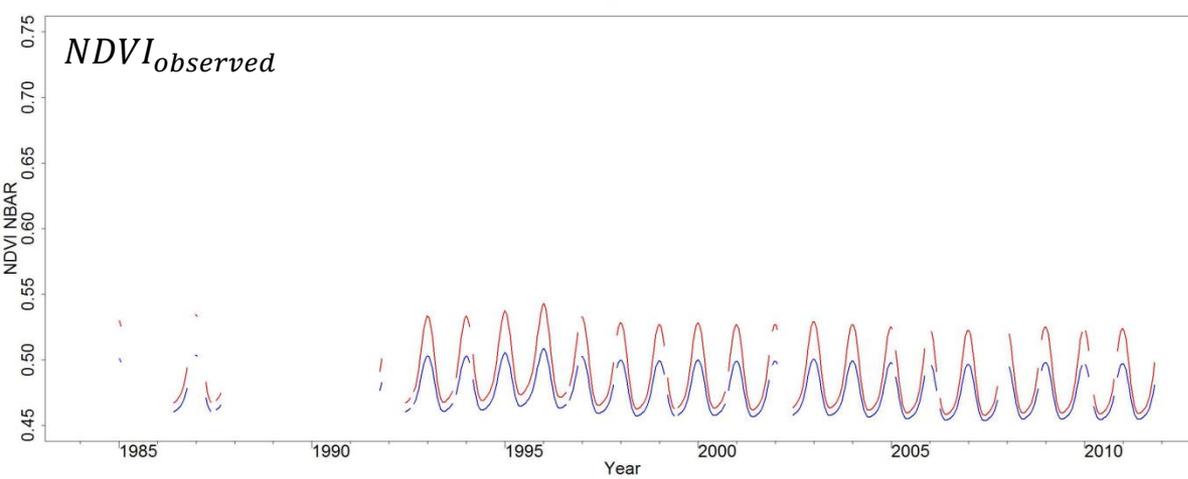
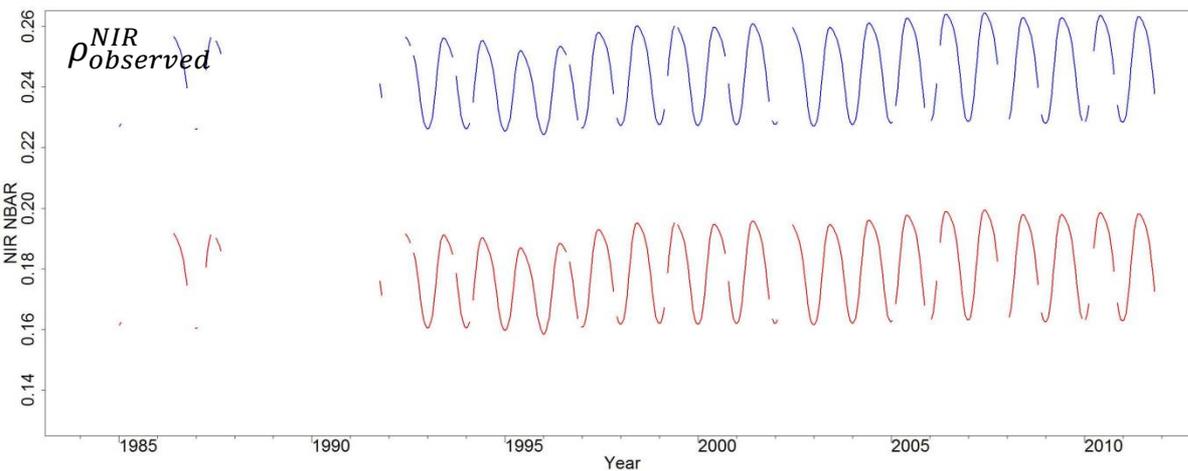
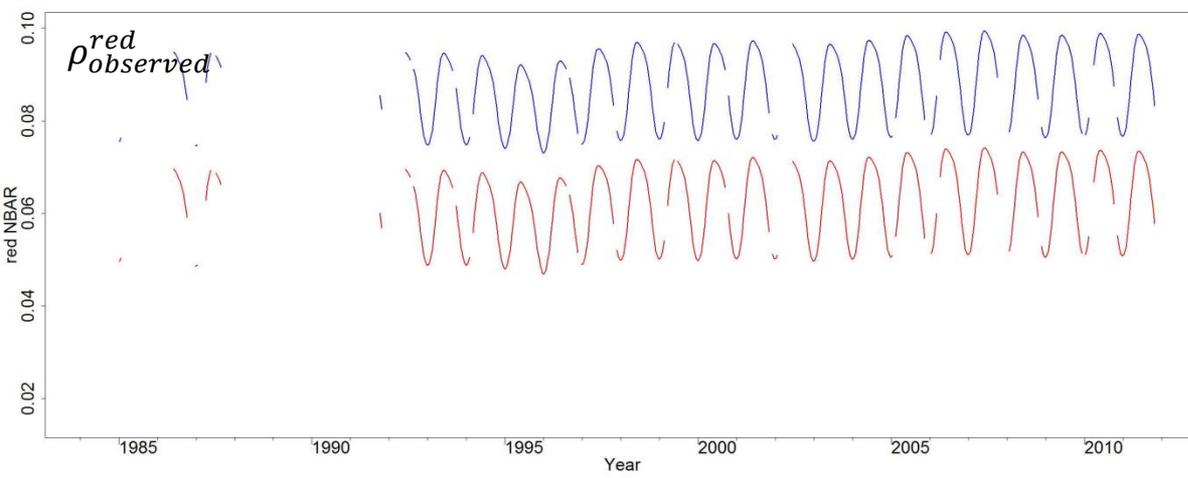


Global WELD NEX Version 3.0 September 2009 30m product
from 15,058 L1T scenes (7,328 Landsat 5 & 7,730 Landsat 7)

Sinusoidal Equal Area Projection

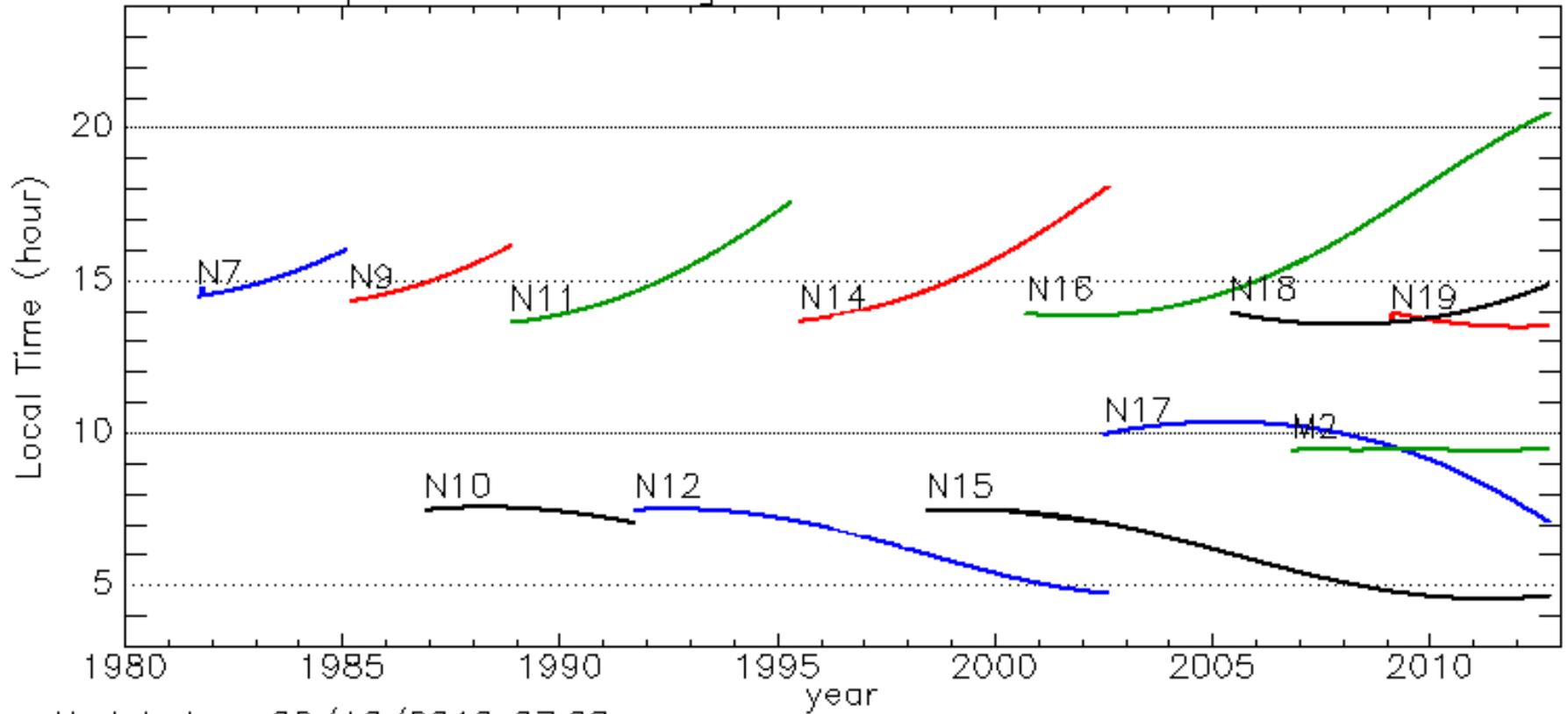


Minnesota (path/row 27/26) modeled NBAR reflectance and NDVI using the fixed 12 month mean CONUS (blue) and closed shrubland class (red) spectral BRDF model parameters and setting the solar zenith to $\theta_{observed}$.



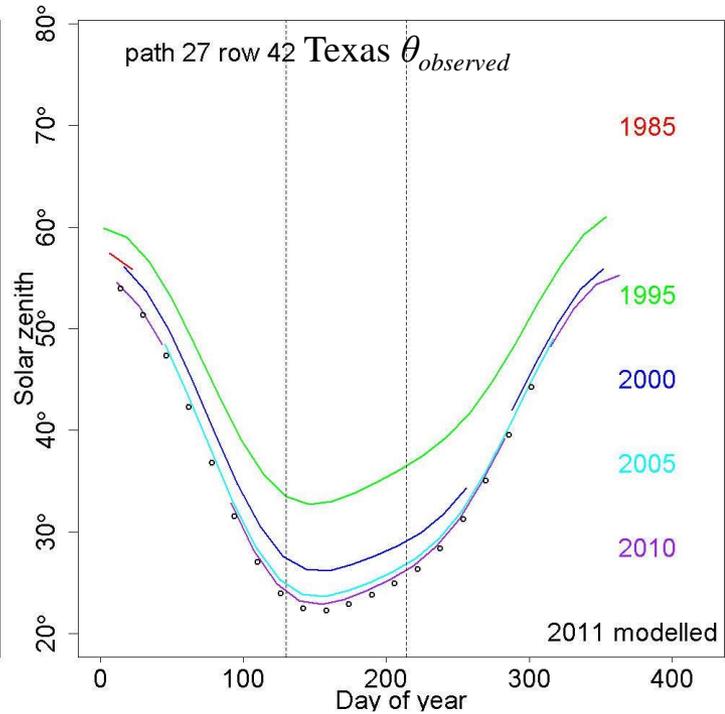
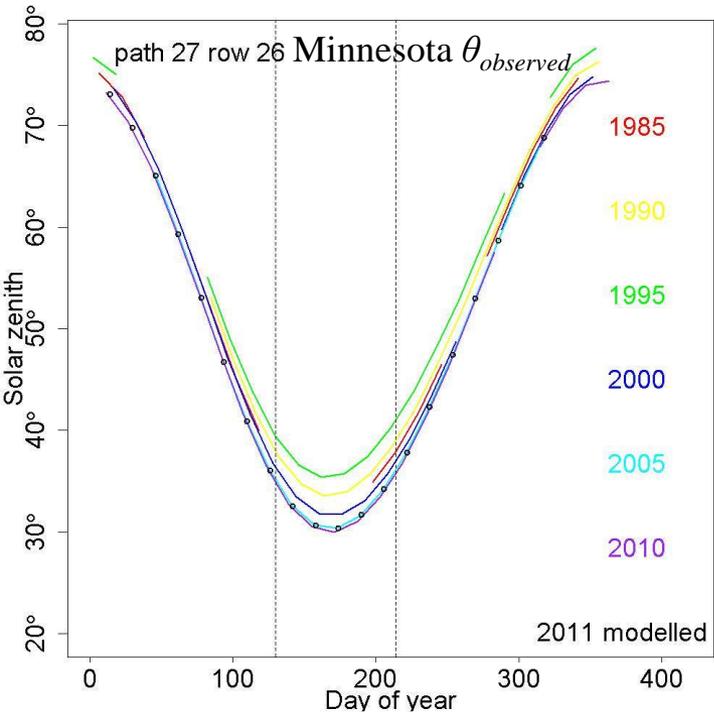
Same as above but for Texas (path/row 27/42)

Equatorial Crossing Time of NOAA Polar Satellites

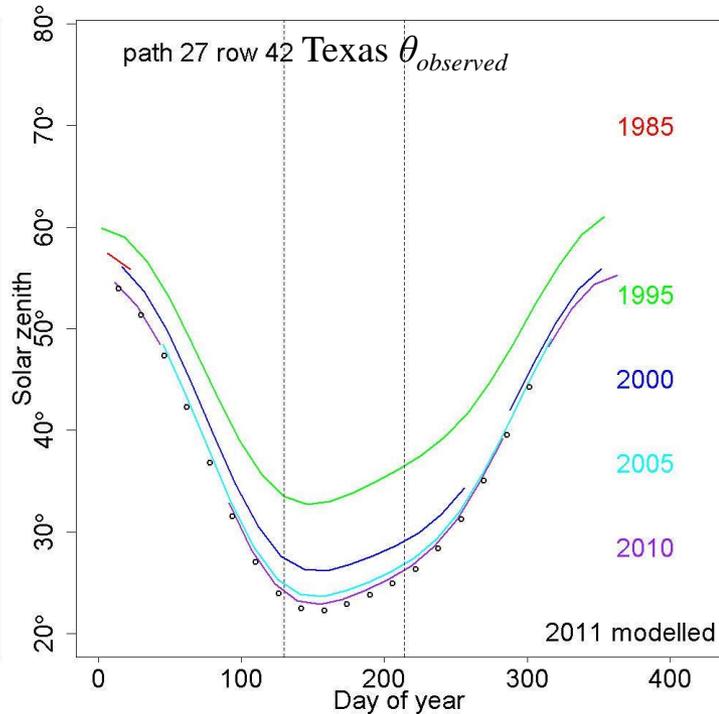
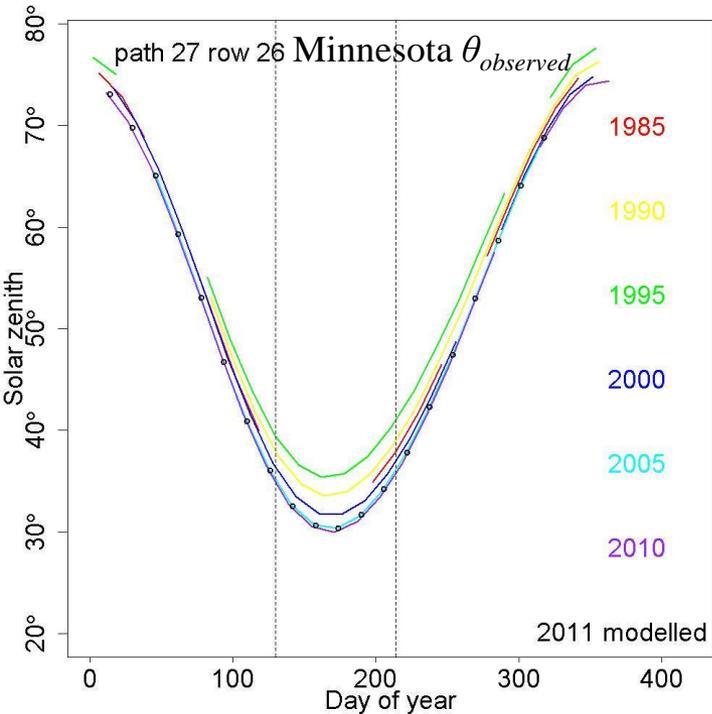


Updated on 09/16/2012 07:00

Satellite orbit can change significantly over its life time



Black dots: $\theta_{reference}$
plotted every 16 days
for the 2011 Landsat
acquisition dates.



Black dots: $\theta_{reference}$ plotted every 16 days for the 2011 Landsat acquisition dates.

